I CLAIM:

1. In a momentum management system for attitude control of a spacecraft, the system having:

a housing to be fixed to the spacecraft;

a momentum wheel rotor in the housing and rotatable about a rotor axis for storing angular momentum;

a gimbal assembly mounting the rotor in the housing;

a drive having an output rotatable about a drive axis, the output being coupled to the rotor for rotating the rotor; and

a torque generation device for imparting torque to the rotor about axes orthogonal to the drive axis,

the improvement wherein:

the gimbal assembly comprises a gimbal ring coupling the drive output to the rotor; and

the gimbal ring includes respective flexure joints connecting the gimbal ring to the drive and the rotor, the flexure joints being configured to permit the rotor to tilt about two flexure axes orthogonal to the drive axis, to incline the rotor axis through a range of angles from about 0 degrees to about 7 degrees with respect to the drive axis under the control of said torque generation device.

2. A momentum management system according to claim 1, wherein each flexure joint comprises a two resilient, non-parallel webs having respective ring ends connected to a body of the gimbal ring and respective mounting ends connected to one of the drive and the rotor.

3. A momentum management system according to claim 2, further comprising a launch restraint system to limit movement of the rotor along the drive axis, the launch restraint system including a stop mounted on the drive output and a cage mounted on the rotor and surrounding the stop.

4. A momentum management system according to claim 3, wherein the launch restraint system further includes deflection stops adjacent opposite sides of each web of each flexure for limiting deflection of the webs.

5. A momentum management system for attitude control of a spacecraft, the system having:

a housing;

a rotor drive having an output rotatable about a drive axis, the drive axis being fixed with respect to the housing;

a gimbal assembly connected to the drive output;

a momentum wheel rotor rotatable about a rotor axis for storing angular momentum, the rotor being mounted on the gimbal to be rotated about the drive axis by the rotor drive and for tilting movement about transverse axes orthogonal to the drive axis;

a torque generation device for tilting the rotor about the transverse axes; and

a sensor for measuring the rotation of the rotor about the rotor axis, the sensor comprising:

a part spherical surface on the momentum wheel rotor;

a pattern formed on the part spherical surface; and

a sensor mounted at a fixed position relative to the housing and positioned adjacent the part spherical surface for detecting the passage of the pattern past the sensor with rotation of the rotor.

6. A momentum management system according to claim 5, wherein the pattern has a leading edge and a trailing edge spaced apart circumferentially of the part spherical surface by a distance that varies with position along the rotor axis and the sensor detects the leading and trailing edges of the pattern whereby the sensor comprises a tilt sensor for measuring the amount of tilt of the rotor about the transverse axes.

7. A momentum management system according to claim 6 wherein the pattern is triangular.

8. A momentum management system for attitude control of a spacecraft, the system having:

a drive having a rotatable output about a drive axis;

a gimbal assembly connected to the drive output;

a momentum wheel rotor rotatable about a rotor axis for storing angular momentum, the rotor being mounted on the gimbal to be rotated by the drive and for rotation about transverse axes orthogonal to the drive axis;

a torque generation device for imparting torque to the rotor about the transverse axes, the torque generation device comprising:

an inner permanent magnet annulus mounted on the rotor, concentric with the rotor axis and with poles spaced apart by a pole spacing dimension along the rotor axis;

an outer permanent magnet annulus mounted on the rotor, concentric with the rotor axis and spaced radially from the inner permanent magnet annulus, with poles spaced apart by the pole spacing dimension along the rotor axis;

a torque coil annulus between the inner and outer permanent magnet annuli and concentric with the drive axis, the torque coil annulus having a core with a dimension axially of the drive axis that is greater than the pole spacing dimension.

9. A momentum management system according to claim 8 including a ferromagnetic cage mounted on the rotor and surrounding the inner and outer permanent magnet annuli and the torque coil annulus.

10. A momentum management system according to claim 9 including a thermal sensor within the ferromagnetic cage for measuring the temperature of the inner and outer permanent magnet annuli.

11. A momentum management system according to claim 10 wherein the cage has an inner surface coated with a high emissivity material.

12. A momentum management system for attitude control of a spacecraft, the system having:

a drive having a rotatable output about a drive axis;

a gimbal assembly connected to the drive output;

a momentum wheel rotor rotatable about a rotor axis for storing angular momentum, the rotor being mounted on the gimbal to be rotated by the drive and for rotation about transverse axes orthogonal to the drive axis;

a torque generation device for imparting torque to the rotor about the transverse axes, the torque generation device comprising:

inner and outer permanent magnet annuli mounted on the rotor, concentric with the rotor axis and spaced apart radially with respect to the rotor axis;

a torque coil annulus between the inner and outer permanent magnet annuli and concentric with the drive axis; and

a ferromagnetic cage mounted on the rotor and surrounding the inner and outer permanent magnet annuli and the torque coil annulus.

13. A momentum management system according to claim 12 including a thermal sensor within the ferromagnetic cage for measuring the temperature of the inner and outer permanent magnet annuli.

14. A momentum management system (10) according to claim 13 wherein the cage has an inner surface coated with a high emissivity material.

15. In a method of manufacturing a gimbal assembly, comprising:

(i) providing a substantially cylindrical inner ring;

(ii) providing a substantially cylindrical outer ring larger than the inner ring;

(iii) mounting the inner ring coaxially within the outer ring;

(iv) forming by wire electric discharge machining openings through opposite lateral sides of said inner and outer rings with substantially planar flexures extending across the openings and inclined to the axes of the rings;

(v) separating the inner and outer rings;

(vi) re-orienting the inner and outer rings to re-align the openings with the flexures perpendicular to one another; and

(vii) welding said inner and outer rings together to form a gimbal ring,

the improvement comprising:

after separating the rings and before re-orienting the rings, removing re-cast material from the flexures.

16. A method of manufacturing a gimbal assembly according to claim 15, wherein the step of removing re-cast material from the flexures comprises treating the flexures with an abrasive slurry.

17. A method of manufacturing a gimbal assembly according to claim 16, wherein the step of removing re-cast material from the flexures further comprises chemically etching the flexures to provide the flexures with a smooth surface finish.

18. A method of manufacturing a gimbal assembly according to claim 15 comprising the further step of surface treating the flexures after removing re-cast material from the flexures and before re-orienting the rings.

19. A method of manufacturing a gimbal assembly according to claim 18 wherein the further step of surface treating the flexures comprises micro-peening.

20. A method of tuning a gimbal ring for use in a gimbal assembly, the ring comprising a substantially cylindrical gimbal ring with a centre of mass, a ring axis through the centre of mass, slots in the ring separating diametrically opposed mounting sections of the ring from the remainder of the ring, and resilient flexures coupling respective ones of the mounting sections to the remainder of the ring, the flexures having flexure axes passing through the centre of mass, the method

comprising removing material from axially opposite ends of the ring so as to maintain the centre of mass of the ring at the intersection of the ring axis and the flexure axes.

21. A momentum management system for attitude control of a spacecraft, the system having:

a rotor drive having an output rotatable about a drive axis at a variable drive output speed;

a gimbal assembly connected to the drive output;

a momentum wheel rotor rotatable about a rotor axis for storing angular momentum, the rotor being mounted on the gimbal to be rotated about the drive axis by the rotor drive and for tilting movement about transverse axes orthogonal to the drive axis;

a torque generation device for tilting the rotor about the transverse axes;

a sensor for measuring the speed of the rotor rotation about the rotor axis and generating a sensor output representative of said speed; and

drive control means responsive to the sensor output for varying the drive output speed so as to maintain the speed of the rotor rotation substantially constant.

22. A combined momentum management and rate sensor apparatus for spacecraft attitude control, comprising:

a rotor drive having an output rotatable about a drive axis at a variable drive output speed;

a gimbal assembly connected to the drive output;

a momentum wheel rotor rotatable about a rotor axis for storing angular momentum, the rotor being mounted on the gimbal to be rotated about the drive axis by the rotor drive and for tilting rotation about transverse axes orthogonal to the drive axis;

a torque generation device for rotating the momentum wheel rotor about the transverse axes to vary the spacecraft attitude;

a sensor for measuring the rotor rotation about the transverse axes, and for generating a sensor output representative of the measured rotations;

a processor for receiving the sensor output and calculating from the sensor output spacecraft rotation rates about said transverse axes; and

an attitude control for controlling operation of the torque generation device in accordance with the rotation rates calculated by the processor.

23. A combined momentum management and rate sensor apparatus according to claim 22 wherein the sensor comprises means for measuring the rotor speed of rotation about the rotor axis.

24. A combined momentum management and rate sensor apparatus according to claim 23 wherein the processor includes notch filters for filtering frequencies from the sensor output equal to the rotor speed of rotation and twice the rotor speed of rotation.